

oxide, and the lithium-manganese complex oxide (first oxide) and this lithium-nickel-cobalt complex oxide (second oxide) were mixed in the ratio by weight of 1:1 to provide a positive active material for use in the positive electrode. Otherwise, the procedure used to construct the battery D of the present invention was followed to construct a comparative battery Y7.

(COMPARATIVE EXAMPLE 13)

In the above Example, the lithium-manganese complex oxide (spinel manganese) represented by the compositional formula LiMn_2O_4 was used for the first oxide. Otherwise, the procedure used to construct the battery D of the present invention was followed to construct a comparative battery Y8.

(COMPARATIVE EXAMPLE 14)

In the above Example, the lithium-nickel-cobalt complex oxide represented by compositional formula $\text{LiNi}_{0.8}\text{Co}_{0.2}\text{O}_2$ was used for the second oxide. Otherwise, the procedure used to construct the battery D of the present invention was followed to construct a comparative battery Y9.

The above comparative batteries Y2, Y3, Y4, Y6 and Y7 are identical to the comparative batteries X1, X2, X3, X4 and X5 constructed in Experiment 1, respectively.

The positive materials of the batteries constructed in the manner as described above are listed in Table 3. In

Table 3, the battery A of the present invention in the above Experiment 1 is also shown.

[TABLE 3]

| | Positive Electrode Material |
|------------------------|---|
| Present Battery D | $\text{LiMn}_{1.95}\text{Al}_{0.05}\text{O}_4$ $\text{LiNi}_{0.6}\text{Co}_{0.3}\text{Mn}_{0.1}\text{O}_2$ $\text{LiCo}_{0.9}\text{Mg}_{0.1}\text{O}_2$ |
| Present Battery A | $\text{LiMn}_{1.95}\text{Al}_{0.05}\text{O}_4$ $\text{LiNi}_{0.6}\text{Co}_{0.3}\text{Mn}_{0.1}\text{O}_2$ |
| Comparative Battery Y1 | $\text{LiMn}_{1.95}\text{Al}_{0.05}\text{O}_4$ $\text{LiCo}_{0.9}\text{Mg}_{0.1}\text{O}_2$ |
| Comparative Battery Y2 | $\text{LiMn}_{1.95}\text{Al}_{0.05}\text{O}_4$ |
| Comparative Battery Y3 | LiMn_2O_4 |
| Comparative Battery Y4 | $\text{LiNi}_{0.6}\text{Co}_{0.3}\text{Mn}_{0.1}\text{O}_2$ |
| Comparative Battery Y5 | $\text{LiCo}_{0.9}\text{Mg}_{0.1}\text{O}_2$ |
| Comparative Battery Y6 | LiMn_2O_4 $\text{LiNi}_{0.6}\text{Co}_{0.3}\text{Mn}_{0.1}\text{O}_2$ |
| Comparative Battery Y7 | $\text{LiMn}_{1.95}\text{Al}_{0.05}\text{O}_4$ $\text{LiNi}_{0.8}\text{Co}_{0.2}\text{O}_2$ |
| Comparative Battery Y8 | LiMn_2O_4 $\text{LiNi}_{0.6}\text{Co}_{0.3}\text{Mn}_{0.1}\text{O}_2$ $\text{LiCo}_{0.9}\text{Mg}_{0.1}\text{O}_2$ |
| Comparative Battery Y9 | $\text{LiMn}_{1.95}\text{Al}_{0.05}\text{O}_4$ $\text{LiNi}_{0.8}\text{Co}_{0.2}\text{O}_2$ $\text{LiCo}_{0.9}\text{Mg}_{0.1}\text{O}_2$ |

(CHARGE-DISCHARGE TEST)

Each of the batteries D and A and comparative batteries Y1 - Y9 constructed in the manner as described above was subjected to a charge-discharge test similar to the above Experiment 1 to determine its 1C capacity retention and 0.2C capacity retention.

The results are given in Figure 4.

As can be seen from comparison between the comparative batteries Y2 and Y3, the 1C and 0.2C capacity retentions can be both improved by incorporation of a dissimilar element (Al) in the first oxide, i.e., the lithium-manganese complex oxide (LiMn_2O_4), in the form of a solid solution. This is because the incorporation of the dissimilar element in the first oxide, in the form of a solid solution, reinforced a crystal structure to the extent that suppressed degradation of the crystal structure with charge-discharge cycling.

From comparison of the comparative batteries Y2 - Y4 to Y6 and Y7, it has been found that the 1C and 0.2C capacity retentions can be both improved when LiMn_2O_4 is mixed with $\text{LiNi}_{0.6}\text{Co}_{0.3}\text{Mn}_{0.1}\text{O}_2$ than when it is used alone in the positive electrode, or, when $\text{LiMn}_{1.95}\text{Al}_{0.05}\text{O}_4$ is mixed with $\text{LiNi}_{0.8}\text{Co}_{0.2}\text{O}_2$ than when it is used alone in the positive electrode. This is because the lithium-manganese complex oxide, when combined with the lithium-nickel-cobalt complex oxide, becomes more effective to suppress expansion and shrinkage of a positive electrode mix in its entirety with charge-